Implementing Haptic Feedback in a Projection Screen Virtual Environment

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Abstract

Haptics refers to the sensing of force, weight, or other physical properties through feeling and touch. The additional information from haptic feedback makes certain engineering design tasks, such as part assembly, much easier than with a traditional computer interface. Haptic feedback, when used in a virtual reality application, is most often combined with either a stereo monitor or head mounted display. In this research, the PHANToM 1.5 haptic device is combined with a projection screen virtual environment, the C6 at Iowa State University, in order to explore the benefits haptic devices bring to this type of immersive environment. To achieve this goal several concepts are presented including: the design of a stand to support the PHANToM in the environment, a virtual volume to scale the PHANToM's physical workspace to a user defined portion of the virtual world, and an application to integrate the PHANToM's GHOST software with the vrJuggler virtual environment software. Two example uses of haptic feedback in the virtual environment are presented: a NURBS surface and a virtual assembly application. The assembly example uses Boeing's Voxmap PointShell (VPS) software to interface with the GHOST software and control the PHANToM. The benefits of haptic feedback in the virtual environment for these examples and some guidelines for using them are presented.

Introduction

A key component of virtual reality (or VR) systems is the ability to immerse a participant in a computer generated virtual environment. Immersion refers to the sense of "being there" that a user feels in the virtual world; the greater the sense of immersion, the more real the virtual world appears [1]. The level of immersion a user feels in a VR environment is related to the number of senses stimulated, such as sight and hearing [2]. However, most virtual reality systems are lacking in a key area of stimulation, namely some form of physical or haptic feedback.

One device capable of providing haptic feedback in a virtual reality simulation is SensAble Technology's PHANToM [3]. This research examines the issues surrounding the use of the PHANToM in a six-sided projection screen synthetic environment, the C6 at Iowa State University.

Implementation

Bringing the PHANToM into a projection screen virtual environment presents several challenges. Since the PHANToM is essentially a desktop device, using it in the large projection screen environment requires the PHANToM to be mobile and adjustable to accommodate a standing user. Second, the PHANToM's 19x27x37 cm physical workspace is much smaller than the projection screen environment's 10x10x10 ft size. Some method must be used to make the PHANToM useful over large portions of the virtual environment. Finally, a program must be written to integrate the operation of the PHANToM with the software controlling the virtual environment.

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Phantom Stand

Physically supporting the PHANToM in the virtual environment was accomplished by designing and building a stand to hold the PHANToM. This stand rolls about on four castor wheels, which may be locked to keep the stand from moving when the PHANToM is in use. Stand height is adjustable from 28 to 42 inches to accommodate different users and postures. Since knowing the orientation of the phantom stand is desirable, magnetic tracking devices, such as the Ascension Technologies MotionStar used in the C6, should be compatible with this stand [4]. Since magnetic materials adversely affect the accuracy of such trackers, the phantom stand was constructed out of bonded PVC plastic and stainless steel hardware. When the stand is in the virtual environment a magnetic tracking device is attached to one of the legs. A model of the stand appears in Figure 1.

Figure 1. Phantom stand

Phantom Volume

To address the mismatch between the PHANToM's physical workspace and the size of the virtual environment, the concept of a phantom volume is presented. This consists of a user-defined quadrilateral volume of space in the virtual environment that correlates motion of the PHANToM's physical endpoint to a virtual position in the environment. This approach is similar to that taken by Preshce and Hirzinger in their work on workspace scaling for teleoperation [5].

A phantom volume is defined by selecting two opposite corners in the virtual space with a wand. The known orientation of the phantom stand, obtained from a magnetic tracker, is used to orient the volume. To aid selection, the volume is dynamically drawn between the first point and the current wand position until a second point it chosen. The completed volume may then be translated about the virtual world and/or scaled to a desired size. Figure 2 shows a phantom volume with a red sphere representing the virtual PHANToM endpoint.

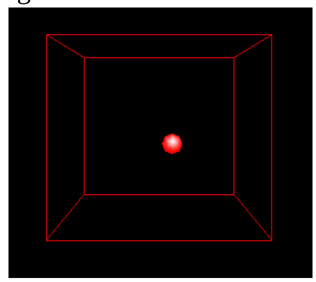

Figure 2. Phantom volume

When using the PHANToM, the virtual endpoint position is confined to the phantom volume, just as the physical endpoint is confined by the PHANToM's physical workspace. Motion of the actual PHANToM is scaled to match motion of the virtual position. This way the limited PHANToM physical working volume can be matched and used over an arbitrarily large space in the virtual environment.

Phantom Driver

The C6 is controlled with the vrJuggler software, a complete framework for virtual reality applications that may be used on a variety of virtual reality devices [6]. Integration of the PHANToM's GHOST software and vrJuggler is handled by the phantom driver program. The phantom driver is a C++ class that builds the haptic scene graph, loads the haptic geometry, positions the virtual PHANToM endpoint in the virtual environment, scales motion of the PHANToM to the phantom volume, and communicates with the rest of the simulation.

The phantom driver's first step is defining the workspace limits of the physical PHANToM device. Since the phantom volume isn't constrained to be a cube, the phantom driver creates the PHANToM's physical workspace to match the form of the phantom volume, so a single scale value suffices to match motion of the PHANToM's physical endpoint to the virtual world. This value, *world_haptic_scale*, is determined from the largest dimension of the phantom volume and the *max_workspace_size* parameter as in equation 1.

$$world\_haptic\_scale = \frac{max\_workspace\_size}{PV[largest\_dimension]} \quad (1)$$

The *max_workspace_size* represents the largest dimension of the PHANToM's physical workspace. In some cases it is useful to confine the PHANToM endpoint to a box of modest size, ensuring that the user doesn't run out of device travel or collide the endpoint with the bulk of the physical PHANToM. At other times it may be desirable to make the physical workspace limits much larger, allowing the PHANToM free movement throughout its entire range of travel. For this work the *max_workspace_size* is set to 120.0 millimeters, which prevents the PHANToM endpoint from colliding with the physical device or the phantom stand.

The phantom driver's also must construct the haptic geometry required by the application. This geometry may consist of simple primitives and/or polygonal meshes. Once the phantom driver has the workspace set up and the geometry loaded, it uses GHOST to build the haptic scene graph. A diagram of this scene graph appears in Figure 3.

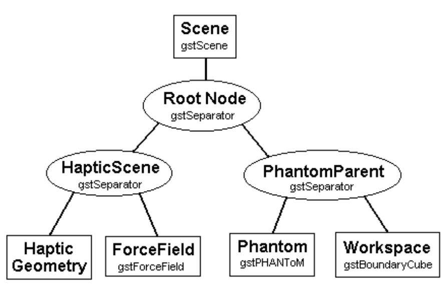

Figure 3. Haptic scene graph

A key feature of this scene graph is the placement of the Phantom and the Workspace objects into the PhantomParent separator. This allows the position of the PHANToM device and its workspace to be translated and rotated in the haptic space to match the position of the phantom volume simply by applying the proper transformations to the PhantomParent, since moving the PhantomParent separator moves both the PHANToM and it's Workspace.

Example Applications

In this research two example applications are presented that demonstrate the advantages of using the PHANToM in a projection screen virtual environment: a NURBS surface exploration example and a virtual assembly application that uses Boeing's VPS (Voxmap PointShell) software.

The NURBS surface example demonstrates using the GHOST software to build the haptic representation of an existing NURBS (Non-Uniform Rational B-Spline) surface. The geometry is then displayed in the virtual environment where the user may define a phantom volume around and interact with any portion of the surface. This application lets the user experience the additional information about an object's shape through the sense of touch while exploring the differences between the PHANToM's physical workspace size and the virtual phantom volume workspace.

The virtual assembly example has the user manipulate the PHANToM in an attempt to install a rudder pedal assembly into a simplified model for the lower front portion of a light aircraft. The haptic feedback provides a fast and intuitive way for a designer to determine if the assembly task can be completed. Boeing's VPS software is used to detect collisions between the pedal assembly and the aircraft structure. Physically-based modeling is used to calculate the haptic forces resulting from any collisions. GHOST is used to return these haptic forces to the PHANToM. The resulting program is capable of manipulating very complicated models at haptic feedback rates [7]. Figure 4 shows the virtual assembly example in use in the C6.

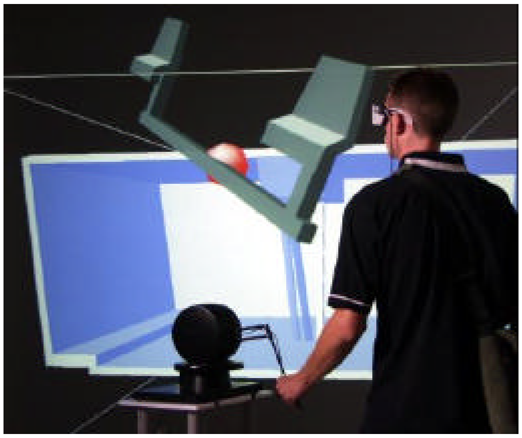

Figure 4. Virtual assembly application with PHANToM

Conclusion

After using this application and experimenting with the examples, some conclusions can be drawn about how haptic feedback and the projection screen virtual environment aid the user in different tasks.

1. Haptic feedback makes manipulating a complex part through confined spaces faster and more intuitive than using a standard keyboard and mouse approach.
2. Being able to touch objects with the PHANToM provides additional information about the geometric structure, which may not immediately be noticeable visually.
3. The projection screen virtual environment makes interference issues encountered in a particular task easy to find and remedy.
4. Since several people may observe the virtual environment and share the PHANToM in the same simulation, the projection screen environment enhances collaboration between users.
5. For the examples presented in this work, the differences in workspace size between the physical PHANToM and the virtual phantom volume appear relatively unimportant.

While the addition of haptics to the virtual environment improved the ability of users to interact with digital models for the examples presented, there are some guidelines that should be followed to ensure a high quality haptic feedback experience in a virtual environment.

1. Avoid positioning much of the phantom in a location that does not align with the user's viewpoint.
2. Avoid making the phantom volume excessively large, as this reduces the quality of the force feedback.
3. Avoid positioning the phantom stand in the direct line of the user's sight.
4. Keep the PHANToM and its stand outside of the virtual geometry.

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References

1. Pausch, R., D. Proffitt, and G. William. *Quantifying Immersion in Virtual Reality*. in *24th annual conference on Computer graphics and interactive techniques*. 1997: ACM Press.
2. Burdea, G.C., *Force and Touch Feedback for Virtual Reality*. 1996, New York: John Wiley & Sons, INC.
3. Massie, T. and J.K. Salisbury. *The PHANTOM haptic Interface: A Device for Probing Virtual Objects*. in *ASME Symposium on Haptic Interfaces for Virtual Environments*. 1994. Chicago, IL: ASME.
4. VRAC, *About the C6*. 2001, Iowa State University.
5. Preusche, C. and G. Hirzinger. *Scaling Issues for Teleoperation*. in *Fifth PHANToM Users Group Workshop*. 2000. Aspen, Colorado.
6. Bierbaum, A., et al. *VR Juggler: A Virtual Platform for Virtual Reality Application Development*. in *Virtual Reality, 2001*. 2001. Yokohama, Japan: IEEE.
7. McNeely, W.A., K.D. Puterbaugh, and J.J. Troy. *Six Degree-of-Freedom Haptic Rendering Using Voxel Sampling*. in *26th Annual Conference on Computer Graphics and Interactive Techniques*. 1999.